NATIONAL WATER QUALITY ASSESSMENT PROGRAM: A PRELIMINARY EVALUATION OF 1990 NUTRIENT LOADS FOR THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN

Elizabeth A. Frick, Susan M. Stell, and Gary R. Buell

AUTHORS: Hydrologists, U.S. Geological Survey, Peachtree Business Center, 3039 Amwiler Road, Suite 130, Atlanta, Georgia 30360.
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INTRODUCTION

The Apalachicola-Chattahoochee-Flint (ACF) River basin, in Georgia, Alabama, and Florida, is among the first 20 study basins in which work began in 1991 as part of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program. NAWQA is an integrated study of surface and ground water, fluvial sediments, and aquatic biota; with major emphasis on nutrients, suspended sediment, and pesticides. Nutrients in the ACF River basin are particularly important because of their effects on the chemical and biological quality of the river system, the 16 reservoirs on the three major rivers, and the Apalachicola Bay ecosystem (Figure 1).

Phosphorous and nitrogen are essential nutrients for plant and animal growth, but high concentrations of these nutrients can adversely affect surface-water quality through eutrophication and excessive aquatic plant growth. Nutrients (particularly phosphorus) are commonly associated with suspended-sediment and suspended-sediment transport is an important mechanism for the transport of nutrients in surface waters within the ACF River basin. Some species of nutrients such as nitrate are soluble and can accumulate in ground water, where the biological uptake of nutrients is relatively small. High concentrations of nitrate can be toxic to warm-blooded animals that drink the water.

This paper presents estimates of loads (unit mass discharge of inputs and outputs) of several nutrients within the ACF River basin. These estimates were made for 1990, the most recent year for which comparative data are available, to help identify the relative importance and general locations of sources and sinks for nutrients, and to assist in the design of a long-term study of surface- and ground-water resources in the ACF River basin.

Nutrient inputs to the ACF River basin from poultry and livestock, fertilizers, atmospheric deposition, and municipal wastewater treatment plants for 1990 are estimated using data of varying accuracy and completeness from National, State, and local agencies. Several sources of nutrients to the ACF River basin for which no estimates are available at this time include: ground water flowing into the basin; organic compounds used in the basin which contain nitrogen and phosphorus; runoff from urban and suburban areas; and decomposition of organic matter in the basin.

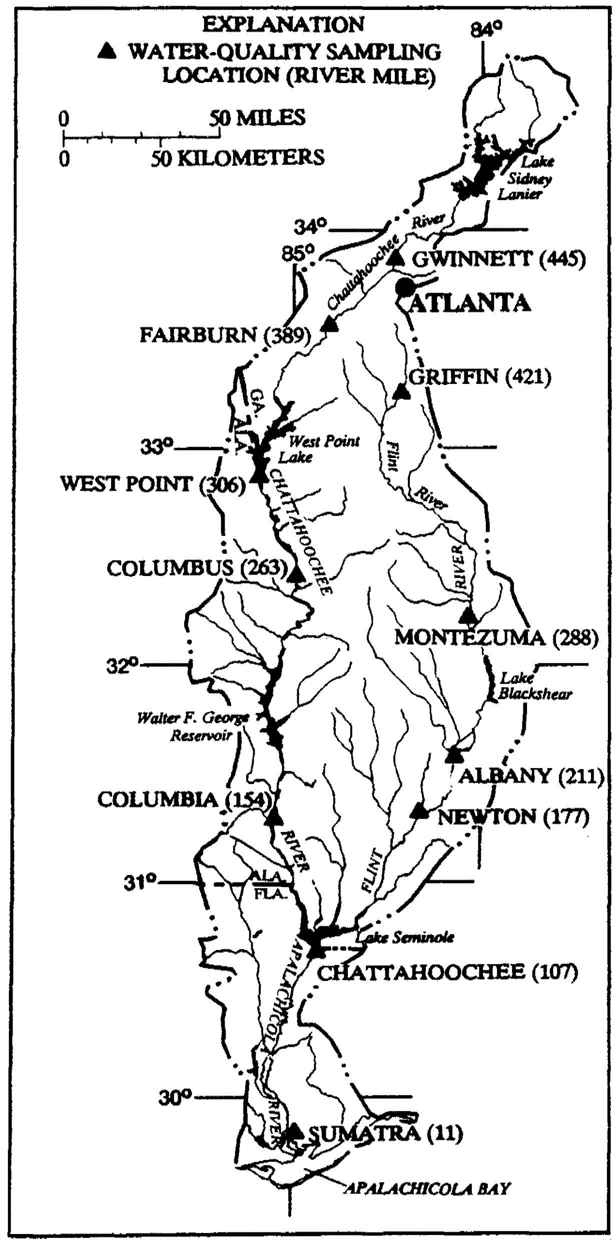

Figure 1. Water-quality sampling locations in the Apalachicola-Chattahoochee-Flint River basin for which nutrient loads are presented in Figure 3.

Nutrient output near the mouth of the Apalachicola River, 11 miles upstream from Apalachicola Bay (Sumatra in Figure 1), is the only estimated nutrient output from the ACF River basin included in this paper. Potential nutrient losses from the basin, which are not quantified in this paper include: nutrients in organic matter exported from the basin, biological denitrification, volatilization of ammonia, and nitrogen in ground water flowing out of the basin (Jaworski and others, 1992). Estimates of nutrient loads at the outflow site near Sumatra and 10 other sites on the main stem rivers (Figure 1) provide a preliminary indication of where major nutrient sources and sinks for the rivers may be located.

Because of the preliminary nature of input and output estimates, no attempt is made to estimate changes in nutrient storage within the basin. Nutrient sinks may be temporary or permanent depending on time scales considered. For example, phosphorus associated with suspended sediment which settles to reservoir bottoms can be resuspended by floods, and biological fixation of nitrogen and adsorption of atmospheric nitrogen by new growth forests can be released decades later.

NUTRIENT INPUTS

Four sources of nutrient input to the ACF River basin, in decreasing order of estimated load, are poultry and livestock, fertilizers, atmospheric deposition, and municipal wastewater treatment plants. Effluent from municipal wastewater treatment plants is the only one of these four input sources of nutrients that is a direct, point source discharge to streams in the basin (except for a few land application systems). The other three sources for which nutrient loads are estimated are from non-point sources that are indirect inputs to ground and surface waters from much broader areas (primarily land surfaces) within the study area. Although relatively small percentages of the nutrients input on land surfaces may reach the ground- and(or) surface-water resources of the basin, these nutrients can have major effects on the hydrologic environments.

In 1990, estimated nutrient loads from poultry and livestock manure included 120,000 tons of total nitrogen (Figure 2a) and 28,000 tons of total phosphorus (Figure 2b), which represent more than half of the estimated nitrogen and phosphorous input to the ACF River basin from the four sources considered. The inputs from poultry and livestock manure primarily are non-point source inputs to the land surface and do not account for losses from volatilization which range from 25 to 80 percent for nitrogen, and from 5 to 15 percent for phosphorous (Kay and Hammond, 1985; McIntosh and others, 1992, p. 2-25). Estimated nutrient loads from poultry and livestock manure were calculated using animal population estimates of approximately 250 million broilers (chickens), 500,000 cattle and calves, and 225,000 hogs and pigs (Alabama Agricultural Statistics Service, 1990; Florida Agricultural Statistics Service, 1990a,b; Georgia Agricultural Statistics Service, 1990; and Strong and others, 1991). Poultry accounts for 89 percent of the nutrient load

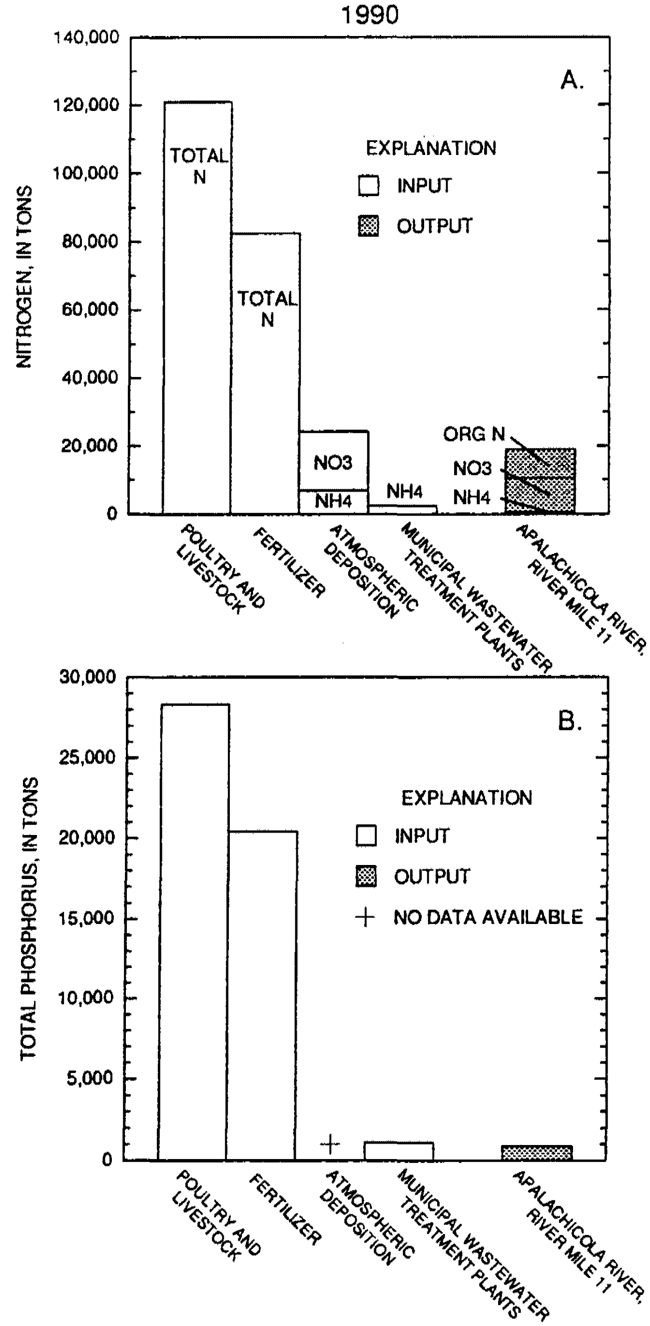

Figure 2. Estimated A. nitrogen and B. phosphorus loads input to and output from the ACF River basin for 1990 (Abbreviation: TOTAL N, total nitrogen; NO3, nitrate; NH4, ammonia; ORG N, organic nitrogen).

from manure in the ACF River basin, and poultry production is concentrated in a 5-county area in the headwaters of the Chattahoochee River (approximately 5 percent of the ACF River basin).

Fertilizer is the second largest non-point source of nutrients to the ACF River basin. Based on estimates for 1990, fertilizer accounted for 82,000 tons of total nitrogen (approximately 36 percent of nitrogen input) (Figure 2a) and 20,000 tons of total phosphorus (41 percent of total phosphorus input) (Figure 2b). Estimates of nutrient loads from fertilizer were modified from load estimates for broad categories of fertilizer sales by county (Janice T. Berry, Tennessee Valley Authority, written commun., 1993). Based on historical fertilizer application, input of nutrients from fertilizers was concentrated in about 10 percent of the basin (approximately 1.3 million acres of agricultural land in 1987; U.S. Bureau of the Census, 1989a,b,c). Fertilizer use was highest in southwest Georgia in the Dougherty Plain area where maximum fertilizer applications by county were 35,000 pounds of nitrogen (as N) per square mile and 6,800 pounds of phosphorus (as P) per square mile. Based on 1987 data, the maximum density of land fertilized by county was about 210 acres per square mile (U.S. Bureau of the Census, 1989a,b,c).

Atmospheric deposition of nitrogen was approximately 25,000 tons in 1990 (Figure 2a), which accounts for 10 percent of nitrogen inputs estimated for this paper. Atmospheric deposition is the only source of nutrients estimated that is distributed throughout the entire study area. The rate of atmospheric deposition is a function of topography, nutrient sources, and spatial and temporal variations in climatic conditions. Fluctuations in the rate of nutrient input from atmospheric deposition is more affected by variations in climatological conditions than other sources of nutrients. Wet deposition of nitrogen was calculated from precipitation chemistry data for ammonium (NH_4^+) and nitrate (NO_3^-) ion concentrations collected weekly at six National Atmospheric Deposition Program stations (Colorado State University, written commun., 1993) in and near the ACF River basin. The estimate of NO_3^- wet deposition was adjusted for urban areas (Sisterson, 1990; and Puckett, L.J., U.S. Geological Survey, written commun., 1993). Dry deposition of NO_3^- (which was estimated to be nearly half of wet deposition of NO_3^-) was calculated based on wet deposition estimates for NO_3^-, and ratios of wet and dry deposition for Alabama, Florida, and Georgia (Sisterson, 1990). No attempt was made to estimate atmospheric deposition of organic nitrogen. Data are not available nationally to estimate phosphorous input from the atmosphere; however, atmospheric deposition of phosphorus probably is minor (R.P. Hooper, U.S. Geological Survey, oral commun., 1993), especially by comparison with nitrogen.

Estimated nutrient loads from municipal wastewater treatment plants in 1990 were 2,200 tons of nitrogen (Figure 2a) and 1,000 tons of phosphorous (Figure 2b). These loads represented 350 million gallons per day of treated wastewater discharged to streams in the ACF River basin and accounted for only 1 and 2 percent, respectively, of nutrient inputs estimated in this paper. Although loads from wastewater treatment plants represent a small fraction of total nutrient loads to the basin, an important difference for surface-water quality and biological communities is that these loads are point sources that are discharged directly into streams and reservoirs as opposed to non-point sources where only a small percentage of the nutrients might reach the ground- and(or) surface-water resources. More than 60 percent of the total discharge from municipal wastewater treatment plants within the ACF River basin in 1990 was in the metropolitan Atlanta area, and slightly less than 10 percent was from the Columbus, Georgia, and Phenix City, Alabama area (Marella, R.L, Fanning, J.L., and Mooty, W.S., U.S. Geological Survey, written commun., 1993). Monthly average effluent discharge, and ammonia and total phosphorus concentrations, were used to calculate nutrient loads from municipal wastewater treatment plants (Georgia Environmental Protection Division, written commun., 1993; Alabama Department of Environmental Management, written commun., 1993; and Florida Department of Environmental Regulation, written commun., 1993). For municipal wastewater treatment plants that did not report nutrient concentrations in their effluent, average concentrations (based on ammonia concentration data for 78 percent and total phosphorus concentration data for 68 percent of effluent discharged within the basin in 1990) were multiplied by the quantity of effluent discharged from these plants in 1990. Data compiled from the U.S. Environmental Protection Agency (USEPA) 1989 Toxic Release Inventory indicate that in addition to the load from domestic wastes, about 75 tons of ammonia solutions and about 56 tons of phosphoric acid were discharged from industrial facilities to publicly owned wastewater-treatment plants in the ACF River basin.

SURFACE-WATER NUTRIENT LOADS AND OUTPUTS

Nutrient loads in surface water within the ACF River basin affect water quality and the trophic status of streams and reservoirs, particularly in the Chattahoochee River downstream from Atlanta, West Point Reservoir, Lake Blackshear, and Lake Seminole. Nutrient outflow from the basin affects the biological productivity in Apalachicola Bay, Florida, through changes in the amount and seasonal patterns of nutrient loading to the Bay.

Nutrient transport in stream, reservoir, and flood plain environments within the basin is dynamic and is influenced by climatic conditions, seasons, location along flow systems, and many other factors. For example, the flood plain ecosystem of the Apalachicola River can be either a source or a sink for nutrients depending on the season, flow conditions, and location (Mattraw and Elder, 1984, p. C33-C37).

Annual estimated nutrient loads at 11 surface-water-quality sampling locations (Figure 1) are shown for 1988 and 1990 in Figure 3 and are based on monthly to quarterly water-quality data stored in the USGS National Water Information System (NWIS) and the USEPA Storage and Retrieval System (STORET). The annual loads for 1988 and 1990 probably are underestimated, because time periods with high flows (when most of the transport of nutrients may occur) were not routinely monitored. Standard errors of load estimates for the Chattahoochee, Flint, and Apalachicola Rivers in 1988 and 1990 are large (commonly up to 50 percent). Because of large uncertainties in estimates of nutrient loads in rivers, estimated loads at a specific location for a given year are less important than: 1) the relative load of nutrients exported out of the basin by the

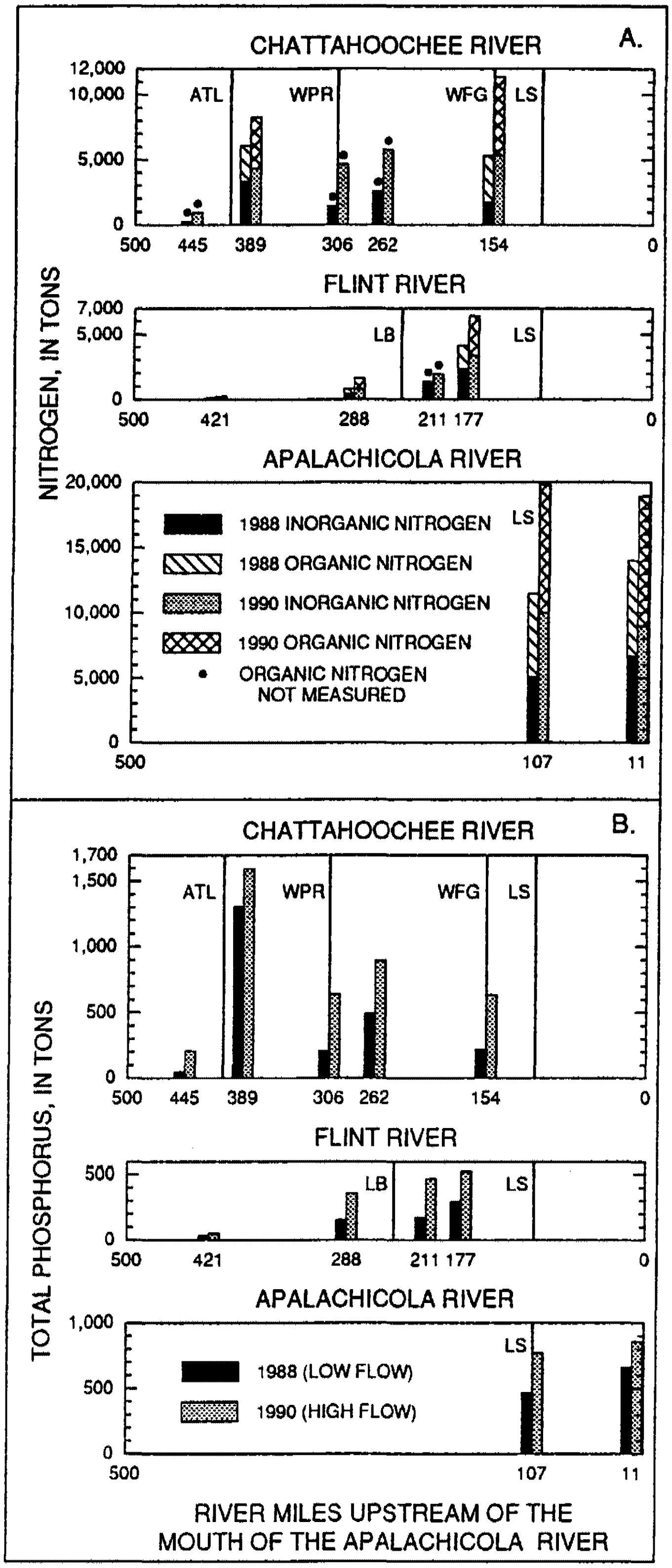

Figure 3. Estimated stream loads for 1988 and 1990 of A. nitrogen and B. phosphorus at selected locations on the Chattahoochee, Flint, and Apalachicola Rivers (Abbreviations: ATL, Atlanta; WPR, West Point Reservoir; WFG, Walter F. George Reservoir; LB, Lake Blackshear; LS, Lake Seminole).

Apalachicola River compared to the load of nutrients imported; 2) the relative difference in nutrient loads at each location between a wet-to-moderate year (1990) and a dry year (1988); 3) the relative difference in nutrient loads among locations along the flow system; and 4) the proportion of nitrogen load in inorganic and organic form (Figure 3).

Estimated outflow of nutrients from the Apalachicola River for 1990 account for only eight percent of the nitrogen (19,000 tons; Figure 2a) and less than two percent of the phosphorus (860 tons; Figure 2b) inputs estimated in this paper. Although these nutrient loads might be underestimated, actual loads in 1990 probably were less than the estimates of 24,000 tons of nitrogen and 1,900 tons of phosphorus transported out of the basin by the Apalachicola River during a one-year period from June 3, 1979, to June 2, 1980 reported by Mattraw and Elder (1984, p. C1 and C14). Their load estimates were based on monthly and high-flow samples, but probably were above average because this time period included parts of two unusually wet years.

As expected, estimated loads were larger at every site for 1990 (a very wet year in the Chattahoochee River watershed and a moderately wet year in the Flint and Apalachicola River watersheds) than for 1988 (a very dry year throughout the ACF River basin) (Figure 3). Analysis of variations in concentrations under different flow conditions has not been completed, but may be helpful in identifying sources of nutrients.

Nitrogen loads in 1988 and 1990 (Figure 3a) tended to increase more uniformly than phosphorus loads (Figure 3b) with increases in streamflow along the three major rivers. Nitrogen and phosphorus loads in the Chattahoochee River increased abruptly just downstream from the metropolitan Atlanta area and decreased downstream of West Point Reservoir. A major reason for the notable decrease in phosphorus is that the transport of phosphorous typically occurs in association with suspended sediment and the 16 reservoirs in the ACF River basin act as temporary and long-term sinks for sediment. For example in 1976 and 1977, more than 60 percent of phosphorus transported in the Chattahoochee River and several tributary streams in the metropolitan Atlanta area was in the suspended rather than dissolved phase (McConnell, 1980, p. 32). In 1988 and 1990, the sum of the calculated phosphorus loads near the terminus of the Chattahoochee and Flint Rivers (510 and 1,100 tons, respectively) was more than the phosphorus load in the Apalachicola River at Chattahoochee (470 and 770 tons, respectively), indicating that probably more phosphorus settled out or was used by aquatic biota in Lake Seminole, than was resuspended or released from biota.

Load estimates for 7 out of 11 stations, where both inorganic and organic nitrogen concentrations were measured (Figure 3a), indicate that between 40 and 75 percent of nitrogen load in the three major rivers is from organic nitrogen. Nitrogen load estimates calculated from just inorganic nitrogen are likely to significantly underestimate actual nitrogen loads within the ACF River basin.

IMPLICATIONS FOR FUTURE STUDY

Estimates of nutrient loads presented in this paper indicate that poultry and fertilizer probably are the two largest non-point sources of nitrogen and phosphorus within the ACF River basin, and that notable increases in nutrients occur in the Chattahoochee River just downstream of the metropolitan Atlanta area. However, the spatial and temporal limits of available data make it difficult to determine: 1) the effect of specific point and non-point nutrient sources on surface and ground water on a regional scale; 2) the timing and mechanism of nutrient transport; and 3) the best land- and water-resource management practices to maintain or improve water quality. The ACF NAWQA sampling network is designed to obtain data that will provide a better understanding of the affects of specific land uses (poultry production, suburban, urban, forest, and agriculture) on surface- and ground-water quality in the ACF River basin, the effects of runoff and wastewater from the metropolitan Atlanta area on the quality of the Chattahoochee River, and the quality of the Apalachicola River flowing out of the ACF River basin and into the Apalachicola Bay.

Proposed nutrient data collection as part of the ACF NAWQA study includes monthly and high-flow surface-water sampling at nine stream-gaging stations; weekly and high-flow surface-water sampling during principal pesticide and fertilizer application seasons (eight to nine months) at three stream-gaging stations; synoptic surface-water sampling at a larger number of locations within the basin; and ground-water sampling at basinwide and watershed scales. Surface-water samples collected as part of the nutrient assessment of the ACF NAWQA study will be analyzed for dissolved nitrite, nitrate, ammonia, organic nitrogen, phosphorus, and orthophosphate; and total phosphorus, and total ammonia plus organic nitrogen. Samples also will be analyzed for suspended sediment concentration and particle size, which are particularly important to better define transport of phosphorus.

Ancillary data such as land use, general soil properties, and hydrogeologic setting will be used to help interpret spatial and temporal changes observed in nutrient concentrations. Analyses of the correlation between nutrient concentrations and streamflows, and the effect of anthropogenic factors (such as changes in discharge locations and volumes from wastewater-treatments plants, changes in treatment processes, phosphate detergent bans, and changes in land use) on nutrient concentrations in ground and surface water are planned.

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